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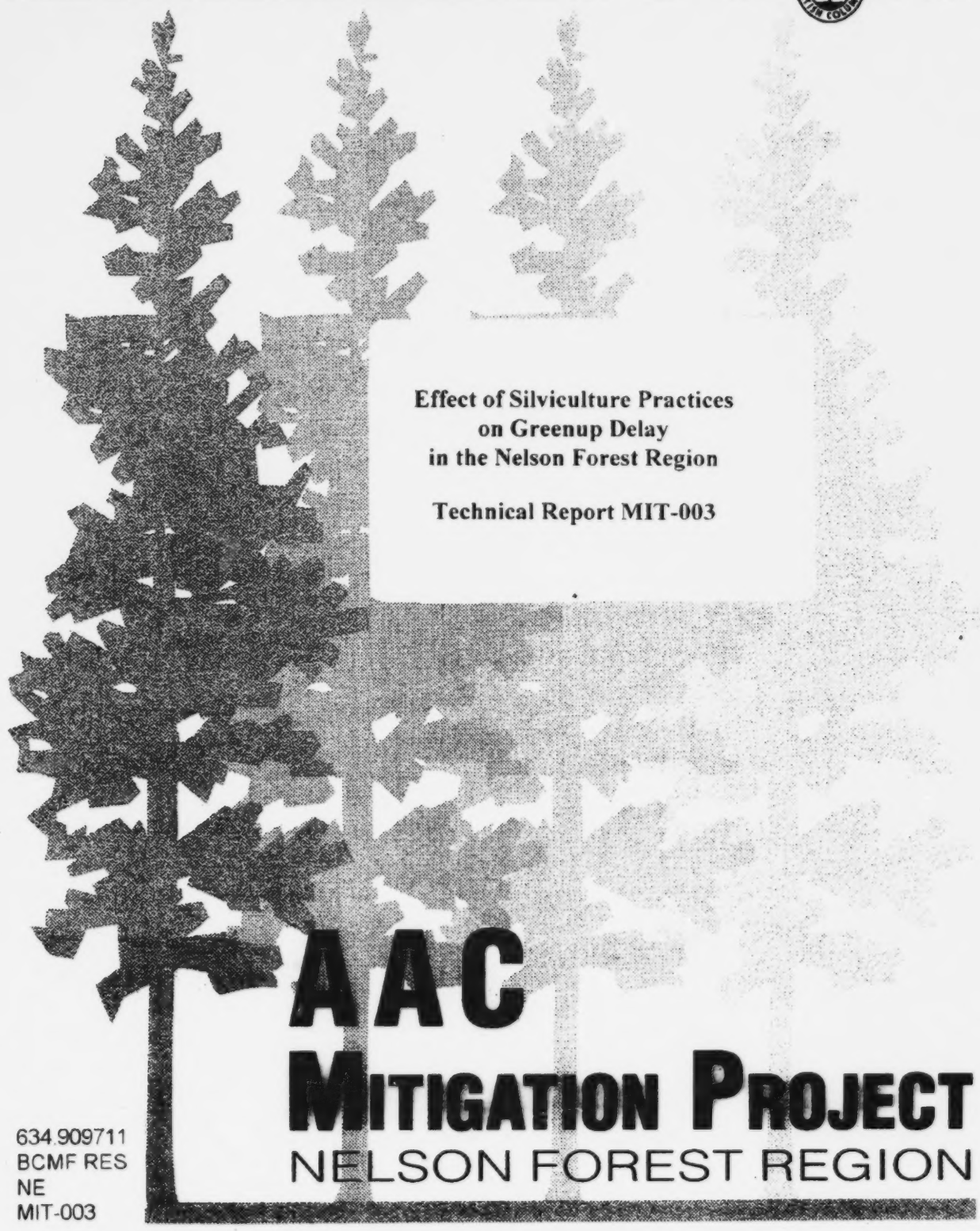

Effect of Silviculture Practices on Greenup Delay in the Nelson Forest Region

Technical Report MIT-003

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Technical Report MIT-003

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Executive Summary

The length of greenup delay in the Nelson Forest Region was investigated. Three different scenarios were constructed: In the Base Case, a site index estimation program was used to construct delays similar to those in the last Timber Supply Review. Current Practice used actual MLSIS/ISIS data to estimate greenup delays. Finally, the effect of Enhanced Silviculture Practices was modeled.

The greenup delay from these scenarios was used to estimate effects on Annual Allowable Cuts in Cranbrook and Revelstoke TSAs. Increases of up to 11.6% in the short term could be attributed to lowering greenup delays through improved silviculture. However, little increase was shown in the long run sustainable yield. If greenup heights are reduced from the current 3 m to 2 m, similar gains would appear in the absence of an improved silvicultural program.

A change in objectives from survival to growth will be necessary if improved silviculture practices are to be used to reduce greenup delays, . This change will necessitate an increase in site preparation and brushing in particular. Expansion of techniques such as herbicide use will be necessary, and more sites (especially drier sites) may have to be treated. Genetically improved seed can provide a large part of the reduction at little cost, while also conferring long term improvements in yield.

In order to achieve these improvements in available wood supply, free growing standards will have to be changed to encourage and enforce better practice. The minimum height requirement will have to be raised and the free growing delay period reduced. The application of these enhanced standards will also have to be planned to maximize the effectiveness of expenditures.

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1.0 Introduction

Greenup delay is the time required for a stand to reach a certain specified average height from the commencement of harvesting. Adjacent stands cannot be harvested by clearcutting silviculture systems until this greenup height is achieved. Different greenup heights are specified depending on the resource values and management objectives in an area. Under the Forest Practices Code, 3 m is the default height. The reduction of greenup delay can increase the short term supply of timber by freeing up adjacent stands for harvesting.

The application of silviculture techniques can have a significant effect on greenup delay. Initial height growth can be increased through the appropriate use of site preparation, planting, and brushing. Current silviculture practice includes some of these techniques, but generally only the activities required to meet the legally mandated regeneration and free growing delays are carried out. Some reduction in greenup from a totally unmanaged stand is achieved. However, considerable further reductions are possible with a focused approach to optimizing tree growth.

In this review, greenup delay and the effect on wood supply were evaluated in the Nelson Forest Region (NFR). By analyzing site index curves, current silviculture regeneration data, and applicable research results, greenup delays for common analysis units and silvicultural treatments were produced. These statistics were used in Cranbrook and Revelstoke Timber Supply Areas (TSAs) to evaluate the effect of various management practices on wood supply. Recommendations for future silviculture activity to minimize greenup delay are provided.

2.0 Methodology

Greenup delays were determined for three different situations, reflecting the base case (greenup delay as estimated for the TSR), current practice (greenup delay estimated using best available current data) and enhanced silviculture practice (greenup delay estimated using reasonable improvements in silvicultural techniques). Analysis Units (AUs) representing the different species groups and site qualities in the NFR were provided by the NFR Planning Section (MacLean 1996). The AUs and associated site indices (SI) that were used in common across all the scenarios are representative of future District Timber Supply Reviews (TSRs). For each Analysis Unit, the times taken to reach 1.3 m (Breast Height), 2m, 3 m, 5 m, and 9 m were calculated. These heights were chosen to reflect the likely range of greenup heights that will be required in future TSRs.

2.1 Base Case

In the previous round of TSRs, greenup delay was calculated using site index estimation programs. A similar methodology was employed in this investigation. For the TSRs completed to date, top height values were used to calculate greenup. However, the present greenup standards require the use of silviculture height (i.e. average height of all the acceptable well-spaced trees only). The net effect is that a longer period of time is now required to achieve the greenup height than formerly calculated.

The FREDDIE Site Index Estimation Program (Polsson 1995) was used to determine the time required to reach various top heights. Because of the discrepancy between top height and silviculture height, the FREDDIE program inputs had to be modified to properly calculate the time needed to grow to the silviculture heights. Advice from the Ministry of Forests Research Branch indicated that 80% of the top height value approximated the silviculture height (Di Lucca 1996). The desired silviculture heights were therefore divided by 0.8 to create adjusted top heights for use in the program. For example, the 2 m greenup height equated to 2/0.8=2.5 m top height.

FREDDIE produces results based on site index and species, not by Analysis Unit (AU). The site index and leading species for each AU were used as the base parameters in FREDDIE. Based upon this data and the adjusted top heights, the program calculated the time needed to reach the various greenup heights from establishment.

Greenup delay includes not only the time needed to grow the trees to a specific height but also the regeneration delay (i.e. period between harvest and the establishment of the next crop). For this base case, regeneration delay was assumed to be the maximum allowed in the Establishment to Free Growing Guidebook. This assumption was made in the last round of TSRs. The Regeneration Delay analysis previously determined this value for each AU (Reichenback 1996). The total greenup delay is therefore the sum of the FREDDIE calculated growing time and the regeneration delay.

The greenup and regeneration delays for the base case are summarized for the various AUs and greenup heights in Table 1.

2.2 Current Practice

The best estimate of greenup delays in future TSRs come from an analysis of the actual results of current silviculture treatments. The Integrated Silviculture Information System (ISIS) and Major Licensee Silviculture Information System (MLSIS) contain height, age, species, and site quality information from actual TSA openings. The height and age information was sorted by species and site quality to match the AUs. Best fit curves were then fitted to the data points using Tablecurve 2D, a computerized curve fitting library (Anonymous 1994). The curve equation was then evaluated for the ages at various greenup heights. The specific fitted curves and equations for Douglas-fir, western redcedar, Engelmann spruce, and lodgepole pine are not included in this report, but are on file in the Nelson Regional Office.

Although the data base contained a large number of points, there was considerable variability. For Douglas-fir, the data was variable enough that no observable differences resulted from site quality. All the Douglas-fir data points were combined into one data set and the resulting curve used for all the Douglas-fir leading AUs regardless of site quality.

Additionally, the data set was most robust (and had the most data points) up to 3 m in height. Data for the 5 m and 9 m greenup heights were either very sparse or missing entirely. The FREDDIE site index program, in contrast, is most useful in the region above breast height (1.3 m). The two approaches were combined to produce a complete set of greenup delays.

The ISIS/MLSIS curve data were used to calculate the time necessary to grow up to 3 m for each AU. FREDDIE was used to calculate the time needed to grow from a 3 m base up to the 5 and 9 m heights. The two times were then added together (ISIS/MLSIS up to 3 m; FREDDIE above 3 m). The result was a complete set of data from 1.3 to 9 m, showing the time required to reach these heights.

The regeneration delay values used in this scenario were the actual delays by AU reported in the previous Regeneration Delay Analysis (Reichenback 1996). The total greenup time was calculated by adding this regeneration delay to the greenup delay estimated above. Currently these values are the best estimate for greenup delay experienced in actual practice in the Nelson Forest Region.

The greenup and regeneration delays for Current Practice are summarized for the various greenup heights in Table 2.

2.3 *Enhanced Silviculture Practice*

Current practice can be improved substantially by intensifying silviculture practice, especially at the regeneration establishment phase. Site preparation, planting, and brushing activities are key to reducing greenup delay. In addition, the use of genetically improved stock is an important factor in improving tree growth.

ISIS/MLSIS do record silviculture activities for each opening. However, it is seldom possible to directly assess the effect of intensive practices on growth in operational plantations. The lack of untreated controls along with the great natural variation in site quality and environmental conditions usually masks the silvicultural treatment effects. However, there are a number of research and operational trials that can be used to estimate treatment effects, as shown in Table 3. These studies were used to estimate the benefit of more intensive silviculture treatment.

With the exception of PROBE, the values contained in Table 3 are based on controlled field experiments results. Operational treatments may show smaller improvements. For analysis purposes, the percentage improvements were averaged for each species and then divided by two. Also, the percentage improvement was assumed to be constant across different site qualities.

Genetic improvements can also increase the potential height growth of plantations. Table 4 provides estimates of the improvement in height growth (as a percentage) due to use of genetically improved stock for each species based on information from the Tree Improvement staff in Research Branch (Yanchuck 1996). These increases are based on current estimates. They may improve as testing allows retention of only the better performers in existing orchards and as new orchards are designed.

The pro-rated silviculture treatment gains and the genetic gains were added together to create a percentage gain for an improved silviculture practices regime. This total percentage was used to reduce the time from establishment to the various Greenup heights estimated in the Current Practice. The Current Regeneration Delay was then added to produce the final Greenup delay for the Enhanced Silviculture Practice. Table 5 summarizes the greenup and regeneration delays estimated for Enhanced Silviculture Practice.

2.4 Confirmation of Results using Regeneration Performance Assessment (RPA) Data

RPA data are available showing the true height growth of plantations established in the Nelson Region. Unfortunately, the RPAs do not extend to all species or to the higher proposed greenup heights due to the rarity of older plantations. However, the data can be used to check and confirm that the Current Practice and Enhanced Silviculture Practice greenup delays are achievable. Because the RPA data was collected from older

plantations with smaller stock types and possibly less effective silviculture techniques compared to current practice, these data may represent the lower end of potential performance.

RPA data are available for lodgepole pine (Thompson 1996) and Engelmann spruce (Thompson 1995). The regression equations developed in those studies were used to calculate time from establishment to the various greenup heights. Good and medium spruce sites were represented by the low elevation (800 m) equation. Poor spruce sites were determined using the high elevation (1600 m) equation. Similarly, good and medium lodgepole pine sites were calculated using an elevation of 1000 m (avg of 800 and 1200 m) and poor lodgepole pine sites using an elevation of 1600 m. The regression equations could not be reliably used at the larger greenup heights, however. Some of the greenup values are therefore unavailable.

By adding the regeneration delays assumed for Current Practice, a total greenup delay was generated. The RPA derived greenup delays are summarized in Table 6. These data were compared to the greenup delays estimated in the Current and Enhanced Silviculture practices.

3.0 Results

3.1 Variation in Greenup Ages produced by the Base Case, Current Practice, and Enhanced Silviculture Practice Scenarios

Base Case vs Current Practice

The Current Practice greenup delays reflect actual growth rates of new regeneration in the Nelson Forest Region. These delays are considerably shorter than those predicted in the Base Case, as shown in Table 7. There are two principal reasons for this difference. First, actual regeneration delays are shorter than the legal maximums assumed in the base case. Secondly, initial growth rates are greater than those derived from the FREDDIE model.

The most significant reductions are in lower greenup heights (less than 3 m), poor sites, and in the initially slower growing species (western redcedar, western hemlock, and Engelmann spruce). The FREDDIE model was used to calculate Current Practice above 3 m, so the absolute difference with the Base Case would remain the same, and the percentage difference would drop. Actual field results indicate that all species, including the species traditionally thought of as slower growing, do in fact grow faster than initially expected. This trend is even stronger on the poor sites.

These large absolute drops in greenup age (up to 14 years at 3 m) indicate that large gains in greenup delay can be had simply by maintaining current silviculture practice and using actual field data. This is particularly true for AUs containing species with slower initial growth and on poorer sites.

Current Practice vs Enhanced Silviculture Practice

Comparison of the data in Table 8 shows that significant gains in greenup delay beyond that available from current practice can be achieved by intensifying silviculture treatments at the regeneration stage. Gains of 3-5 years at 3 m are possible. These gains translate to 7-15 years at 9 m height.

Since Current Practice already includes some basic level of silviculture activity, the gains are not as dramatic as those from the Base Case to Current Practice. However, they are still significant.

Enhanced Silviculture Practice vs RPA data

The available RPA data was compared with the Enhanced Silviculture Practice projections in Table 9. In most cases, the RPA data showed greenup ages similar to and often less than those from the Silviculture Treatment scenario. Unfortunately, RPA data is only available for lodgepole pine and Engelmann spruce, and only reliable above 3 m in height for lodgepole pine. However, the available data comparisons indicate that the

Enhanced Silviculture Practice projections are reasonable. In fact, the RPA projections may be conservative as stock types and site treatments have improved since those plantations were established. Future studies could show even lower greenup ages.

3.2 AAC Impacts of Greenup Ages produced by the Base Case, Current Practice, and Enhanced Silviculture Practice Scenarios

The Base Case, Current Practice, and Enhanced Silviculture Practice were assessed for their impact on AAC assuming a minimum 3 m greenup height. The three scenarios were run in the Cranbrook and Revelstoke TSAs using FSSIM. Table 10 shows that significant gains in available wood supply are possible, especially in the short term.

Revelstoke TSA

The effects of various greenup scenarios on the Revelstoke TSA are shown in Figure 1 and Table 10. In the short and medium term (the next 3 decades), gains of 2,800 m^3/yr (1.78%) are indicated simply from using Current Practice, the best available data. Enhanced Silviculture Practices offer gains of a further 4,156 m^3/yr (2.64%) for a total of 6,956 m^3/yr (4.43%). Of this increase, 1,704 m^3/yr (1.08%) are attributable to genetic improvement. The remainder can be attributed to changing silviculture practices. In this TSA, factors other than greenup delay are more constraining to short term timber supply.

The impact on the long term is also small. The Enhanced Silviculture Practice run shows a gain of only 2,000 m^3/yr (1.67%) 14 decades from now. This result is not surprising, as silviculture treatments to increase early height growth do not affect site index.

If the minimum greenup height is reduced to 2 m, then no significant difference between the greenup scenarios exists in either the short or long term (MacLean 1996). The different scenarios reduce the time to reach 2 m and 3 m by a similar percentage. However, the absolute age difference to reach 2 m is naturally much lower than for 3 m. Other factors then become more limiting than greenup age. The result is that the use of a 2 m minimum greenup height produces volumes equivalent to the 3 m greenup using all the Enhanced Silviculture Practices.

Cranbrook TSA

For the purposes of this analysis, the Kootenay Boundary Land Use Plan (KBLUP) greenup age was chosen as the point of comparison. The original Base Case greenup ages were quite long for the Cranbrook TSA because of the preponderance of lower site qualities. When compared to the Current Practice scenario, greenup ages were much higher than the Base Case. The KBLUP information was felt to be more realistic, although the greenup differences are less striking.

The effect of reduced greenup delays in the Cranbrook TSA is much higher than that evident in Revelstoke. The results are shown in Figure 2 and Table 10. In the short term (the next 3 decades), the Current Practice scenario gives gains of 29,548 m^3/yr (4.01%) over the Base case. The Enhanced Silviculture Practice run demonstrates further gains of 56,119 m^3/yr (7.63%) for a total of 85,667 m^3/yr (11.64%). About 23,009 m^3/yr (3.13%) is the result of genetic improvement; the remaining 33,110 m^3/yr (4.50%) is the result of improved silviculture practices. The benefit is not so much an increase in the absolute cut level, as the maintenance of existing cut levels (especially for the first two decades) while the base level is forced to drop. This gain is quite significant and could have a major impact on the wood supply situation in this TSA.

In the long term, gains are not as large. The total gain from the Enhanced Silviculture Practice run are only 10,000 m^3/yr (1.22%). Current Practice gains are only half this amount. This result is to be expected, as silviculture treatments to increase early height growth do not affect site index.

The bulk of the increase is due to the practice of more intensive regeneration silviculture. The effect of Current Practice over the Base Case is substantial at first, but declines after the first decade and does not become significant thereafter. The use of Enhanced Silviculture Practice provides most of the wood supply increase after the first decade. Enhanced Silviculture Practice can provide an important mitigative effect in this TSA.

If the minimum greenup height is reduced to 2 m, then no significant difference between the greenup scenarios exists in either the short or long term (MacLean 1996). The different scenarios reduce the time to reach 2 m and 3 m by a similar percentage. However, the absolute age difference to reach 2 m is naturally much lower than for 3 m. Other factors then become more limiting than greenup age. The result is that the use of a 2 m minimum greenup height produces volumes equivalent to the 3 m greenup using all the Enhanced Silviculture Practices.

Regional Effect

The effect of reduced greenup ages varies significantly by TSA. In TSAs where greenup is a severe limitation to available wood supply, the Enhanced Silviculture Practice scenario can provide fairly large mitigative effects. Golden, Cranbrook, and Kootenay Lake fall into this category. Invermere and Arrow TSAs have wood supply moderately limited by greenup delay with a correspondingly lower mitigative effect. Even in TSAs where greenup is not as limiting, such as Revelstoke and Boundary, there is some improvement in potential wood supply. Perhaps just as important, any reduction in greenup ages increases the harvesting flexibility of Districts and Licensees(MacLean 1996). This effect may not be well reflected in wood supply models, but nevertheless is important in the practical day to day management of cutting authorities.

These gains are predicated on the maintenance of the existing 3 m greenup height. The analysis shows that similar gains can be achieved by reducing the default greenup height to 2 m. The original 3 m height appears to have been chosen administratively as a provincial standard; a new lower height may be appropriate for TSAs in the Nelson Forest Region.

In the longer term, reducing greenup ages does not give large increases in potential wood supply. However, there are a number of unmodelled factors that will influence the long run sustainable yield. Genetic improvement was only used to increase early height growth in this study. In reality, improved stock will increase the site index. This increase would directly influence long term wood supply. The Current Practice and RPA data indicate much higher early height growth than predicted by FREDDIE. This discrepancy may indicate that site indices for the Region are underestimated, as the old growth site index (OGSI) project may yet quantify. Again, an increase in site index values - for whatever reason - would directly affect long term wood supply. Enhanced Silviculture Practice would increase the distribution and stocking of crop trees. Also, any increase in early height growth (even if not sustained over the rotation) will decrease the final rotation age and effectively increase MAI. These last two factors would also tend to increase the potential long run sustainable yield.

4.0 Discussion

4.1 Silvicultural Practices to Reduce Greenup Delay

The underlying principle for the silvicultural practices needed to reduce greenup delay can be summarized simply as **maintaining an optimum seedling environment**. As with many simple and seemingly self-evident statements, the biological rationale and practical application can be complex and difficult.

Many studies of tree growth have shown the existence of threshold values. That is, as resources to trees increase, there is little improvement in tree parameters until a threshold level is reached. At that point, there is a rapid, often exponential increase in tree parameters. Most often these parameters are expressed as tree survival and growth.

Survival thresholds tend to be fairly low. As resources increase, survival increases rapidly. At moderate levels of resources, survival starts to level out and further increases provide little if any gain.

Tree growth, on the other hand, shows a different trend. There are a number of different measures of growth, including height, volume, diameter, crown volume, etc. However, they all react similarly to changes in levels of resources. As resource levels increase, growth increases only slowly at first. At some point, the threshold level is crossed. Growth increases significantly and often exponentially after this point. Height growth in particular has a relatively high threshold, as trees allocate growth to diameter first. For example, some studies indicate that vegetation cover must be below 20-30% to demonstrate significant height growth. (Comeau 1996; Dunsworth and DeYoe 1990)

Another complicating factor for tree growth is the determinate nature of many of our commercial conifer species, such as lodgepole pine, Engelmann spruce, and Douglas-fir. For determinate species, the current years growth is dependent upon the primordia developed in buds grown the previous year. As a result, current growth is determined not only by current growing conditions but also by the previous years growing conditions (Scagel 1995).

Finally, the relatively short growing season on many sites in the Nelson Forest Region can seriously impact potential growth. If resources are limited during this time, especially in late spring and early summer when optimum climatic conditions tend to prevail, tree growth will be substantially reduced. Even a relatively short period of deprivation at a critical time can result in large losses. Needle size and type (shade or sun) are determined within a short period but have large future impacts on the amount and efficiency of future photosynthetic capacity. Also, early growth is limited until trees get above the spring snowpack line. Evergreen conifers above this level can photosynthesize during spring as air temperatures are sufficiently high and the soil is not frozen. Quickly getting trees to this level (generally above breast height) will result in increased future height growth.

There are a number of implications resulting from these biological realities if early height growth to reduce greenup delay is to become an operational goal.

1. **High levels of vegetation control in the seedling growing space are needed to get growth response.** A reasonable target would be to keep vegetation cover below 20% within 1 m of seedlings, based upon work in B.C. and in the U.S..

2. **Good seedling growing conditions must be created initially.** Seedlings must be able to grow at their potential as soon as they are planted. Effective site preparation is a key activity in increasing height growth.

3. **Good seedling growing conditions must be maintained.** During the growing season seedlings must not be slowed down. More importantly, seedlings must be kept in good growing conditions until the trees have dominated the site. This period of time is 3-5 growing seasons.

Any potential silviculture practices to increase height growth must follow these principles.

Planting Stock

It is a well known phenomenon that larger seedlings grow faster than smaller ones. Clearly, by planting larger trees greenup height will be reached sooner. However, there are practical upper limits to stock size due to cost and planting difficulty. The Nelson Region has historically used a high proportion of large stock types such as PSB 415. This trend appears to be continuing (Madill 1996). As a result there appears to be little opportunity to further increase seedling size.

Genetically Improved Seed

The first generation of genetically improved seedlings is already available, and these trees display significant early height growth gains over wild seed. Because seed is only recently available its use is not reflected in current reforestation growth statistics, but this will change over the next few years as improved seed becomes the standard.

In the future, genetic gain can result in height growth increases averaging 14% or more (Yanchuk 1996). Disease resistance (e.g. Blister Rust resistant white pine, leader Weevil resistant Engelmann spruce) will effectively improve growth by reducing pest damage. Better selection and testing of orchard trees, along with new propagation technology, will provide foresters with a supply of more reliable and faster growing planting stock. It is important to realize that this gain will only become available if resources are put into the tree improvement program. The Ministry of Forests and/or FRBC (Forest Resources Corporation of B.C.) will have to continue to support this program to ensure an improved seed supply and potential AAC gains are avaiaable.

Although this discussion is focused on early height growth, the largest benefit of improved seed is likely to be in final volume. Genetic improvement effectively changes site index. Trees are not only taller, but have increased diameter and volume as well. The benefit of using improved seed extends not only to reductions in greenup delay, but increases long run sustainable yield.

Site Preparation

Site preparation is probably the silviculture treatment with the most effect on early height growth. It can potentially ameliorate multiple limiting factors. Appropriately prescribed treatments can:

- Warm soil to create a longer effective growing season;
- Control vegetation competing with seedlings for light, moisture, and/or nutrients
- Mix soil to incorporate organic matter and improve soil properties
- Improve moisture regimes by drying out wet soils and conserving moisture on dry sites

For example, the most common limiting factors to growth in the Nelson Region are cold soils, low moisture during the growing season, and vegetative competition. Appropriate site preparation can ameliorate all three concerns. For example, mounding can provide soil warming and control vegetation. Disk trenching can increase soil moisture by providing a receiving microsite and controlling grass. Prescribed burning can control vegetation and warm the soil.

Only planting has a larger effect on reforestation success. Site preparation not only has a large, but a lasting effect on initial seedling growth. This property makes it a key treatment for reducing greenup time.

Brushing

Brushing is a plantation maintenance activity required where initial planting and site preparation have not sufficiently controlled vegetation around the seedlings. There are two factors critical to brushing so that height growth is maximized:

- vegetation control must be high, so that less than 20% vegetation cover remains near the seedling. Where moisture or nutrient competition is the problem, vegetation roots must be controlled, not just above ground stems.

- timing is critical; control must be pro-active and take place before the trees are suffering any competitive stress. Control must be maintained during the growing season until the trees have dominated their local microsites.

In order to meet these requirements in a cost effective manner, herbicide use may be necessary. Herbicides generally provide a longer lasting and higher level of vegetation control than other methods. Spot treatments around individual crop trees can be used to minimize impact on non-target vegetation.

The use of a Competition Index (CI) to measure competition and to predict future vegetation levels may be a convenient method of managing these factors. A competition index integrates vegetation measures (e.g. height, cover) often with some measure of seedling size (e.g. height) into one number describing the amount of competition. Management decisions such as treatment level or acceptable impact can then be described using CI.

Potential Synergistic Effects between Genetics and Silviculture Treatments

Although not easily quantified, there is some evidence of synergistic effects between silviculture treatments and genetics. Clearly even a genetically improved seedling will not be able to grow quickly if its environment is unfavorable. Providing a good growing environment allows a tree to fully express its genetic potential. Work in other jurisdictions has shown a synergistic effect between seed source and vegetation control, for example (Roth and Newton 1996). This effect needs to be more thoroughly explored but may provide the basis for future reductions in greenup delay.

The silvicultural practices that can contribute to reduced greenup delay can be summarized in three points:

- Prepare planting sites to provide optimum initial growing conditions for seedlings;
- Plant the largest possible, best quality stock (genetically improved if available) as soon as possible, and;
- Control competing vegetation (if required) to maintain optimum growing conditions for the tree until it dominates its local microsite.

4.2 *Status of Current Silviculture Practice*

There are some trends in current silviculture practice which will affect greenup and regeneration delay in the future. In particular, the amount and type of site preparation, planting, and brushing are important (Tables 11-17).

Site Preparation

Examination of the amount of area site prepared on blocks considered stocked shows that 61% has been treated with prescribed fire, mechanical methods, or some other means (Table 11). A somewhat different picture emerges if all openings harvested from 1990 to 1994 are considered as in Table 12. During that time period, 42% of the area logged has been site prepared. Even more disturbing, the trend over the years has been for the amount of area site prepared to decline over time from 59% of the blocks logged in 1990 to 19% of the 1994 blocks. Table 14 shows this trend is consistent over all Districts. Reductions in prescribed burning have accounted for much of the decrease. Although the amount of mounding (a particularly effective treatment for increasing growth on cold wet sites) has increased substantially over the last few years, it still accounts for only a small percentage of the total area harvested (estimated less than 5% of area site prepared). Mounding cannot make up for the overall drop in goal achievement (Madill, 1996).

Much of the success of past plantations as documented in the Current Practices scenario may be due to this higher use of site preparation in the past. The fact that a larger proportion of site prepared blocks are stocked compared to unprepared blocks is consistent with this explanation. Given that appropriate site preparation increases reforestation success and tree growth, the drop in site preparation is a worrisome trend.

Planting

Almost 77% of stocked openings were planted, as shown in Table 17. This high proportion is consistent with the generally short regeneration delays experienced. Similarly, most planted stock is ordered in the larger container sizes (i.e. PSB 415's). The use of even larger stock sizes (i.e. PSB 615's or equivalent) is unlikely to be used because of the dramatic increases in growing, handling, and planting costs associated with them. The large cost increases would provide only a small improvement in performance.(Madill 1996). Increases in the amount of planting and the size of stock cannot be justified by significant improvements in results.

The only genetically improved seed available at this time for most of the Nelson Forest Region is Engelmann spruce. Current gains in height growth are small (3%) but can be expected to increase to as much as 12% as seed orchards are rogued. Other species are not available in the short term but could be available in production quantities within 10 years (Yanchuk 1996). Overall, height gains of 20% or more are feasible. The large potential gains make it essential that the Tree Improvement program is maintained.

Brushing

The area brushed on stocked openings totals about 12% of the logged area (Table 13). Similarly to site preparation, the proportion drops significantly to under 9% of the areas logged from 1990-1992 as shown in Table 12. The trend over time suggests that the low brushing accomplishments are decreasing further. Even these low percentages are inflated by a multiple of 2 or more, as the bulk of brushing in the Nelson Forest Region is manual. Most manual brushing blocks are treated at least twice. The hectares treated in Tables 12 and 13 include these repeat treatments. Overall, the proportion of logged areas brushed ranges from 4 to 6%of logged areas, and it is decreasing over time.

Within Districts. Tables 15 and 16 shows similar trends. One District, Revelstoke, has a much higher proportion of brushing compared to others. Nearly 73% of the area logged has been brushed. This is consistent with the recognized brush potential in that area. The apparently high amount of brushing is also artificially boosted by the need for 2 or even 3 manual treatments. Brushing in Revelstoke is also declining over time, however. Without Revelstoke the proportion of brushing in the Region would be even smaller In general, those Districts within the moist or wet climatic regions (Golden, Revelstoke, Arrow, and Kootenay Lake) do more brushing than those Districts in dry climates (Cranbrook, Invermere, Boundary).

These brushing trends are a major concern when considered in conjunction with the same trend in site preparation. Appropriate site preparation can reduce the need for brushing, particularly where survival is the main objective. However, raw planting on unprepared ground will not optimize tree growth. Slower growth and a higher risk of failure are more likely.

Summary of Current Practice Trends

The array of silviculture practices that have resulted in the current state of plantation success and growth are not static. In some cases, such as use of genetically improved seed, there are clear improvements over time. However, other practices such as site preparation and brushing are actually decreasing as a proportion of area logged. This situation may be acceptable if meeting the minimum free growing standards is the target. However, it is important that silvicultural practices be carried out more widely if tree growth is to be optimized on the ground and greenup delays reduced.

5.0 Recommendations

Based upon the results of this investigation, a number of recommendations for reducing greenup delays in future TSRs can be made.

5.1 Use Current Greenup Delay in Future TSRs.

Past TSRs have used site index curves to estimate greenup delays. The data upon which these curves are developed are known to be weak in the early years of tree development, precisely the area most important to calculating greenup delays.

The methodology developed here to assess Current Practice free growing delay can readily be used in future TSRs. Regional staff can fit height age curves to District data sets in the upcoming TSR process. No change in management practice is required to reduce greenup delay from past practice. There will be an immediate and clear benefit in terms of a more accurate assessment of wood supply.

5.2 Implement a Silvicultural Growth Strategy to Reduce Greenup Delay

The silvicultural priority of licensees in most TSAs has been to meet regeneration delays and to ensure stands will become free growing before the (rather lengthy) free growing delay expires. The low minimum height requirement has meant that growth has not been a priority. Instead, survival is the key management requirement.

If silvicultural techniques are to help reduce greenup delays, *priorities must shift from survival to growth of forest plantations*. This change means that silvicultural regimes that optimize early plantation height growth must be exercised consistently. Establishment and good early height growth are the result of an inter-related package of silviculture techniques and cannot be attained simply by mandating one or another treatment. This package will include the following elements.

Site Preparation

As discussed earlier, site preparation is a key activity in optimizing early seedling growth. Properly prepared sites provide a suitable environment from the moment a tree is planted. Site preparation should be considered on sites where it is not required to maintain survival but could increase early height growth. Growth limiting factors must be a large consideration in selecting a method.

For areas logged in 1994, only 19% of harvested areas were site prepared. Some of this area is site prepared for planter access or hazard abatement but has little impact on tree growth (e.g. spot burns). *Some of the current site preparation goals should be shifted towards treatments more likely to increase early growth, such as mounding and*

broadcast burning. The proportion of logged areas site prepared specifically to increase growth could increase significantly up to 60%.

Planting and Tree Improvement

Most sites are currently planted. In addition, larger stock types have long been standard practice in many parts of the Region. There is not likely a large gain to be made here. However, planting may reduce regeneration delay in some specific sites where quicker greenup is desirable. *No significant increase in planting effort or stock size is required, but the current level of effort must be maintained.*

Genetically improved stock is increasingly available and must be used where possible (Forest Practices Code) This change is currently happening without any additional effort on the part of the NFR. However, further advances in tree improvement will require greater and more secure funding. *The Nelson Region should support high gain tree improvement efforts fully.* A regional Tree Improvement Cooperative in partnership with industry is one effective way to meet this goal. This proposal has already been made by Silviculture Practices Branch and is even more attractive considering current funding constraints. The immediate effect will be on short term wood supply as greenup delays are reduced. However, there are also significant long term benefits as the use of genetically improved trees is equivalent to an increase in site index.

Brushing

The brushing program in the Nelson Region has always been and continues to be aimed at maintaining adequate survival. The priorities have been competition for light in the moister ecosystems, undertaken after vegetation growth is obvious. Most brushing is manual (95%).

The implications of a growth strategy for brushing are that activities be pro-active, have a high level of control, and that control be maintained for 3-5 years. In addition to moist ecosystems, dry sites with grass/forb competition may also need treatment. Pro-active treatments will need to take place before vegetation becomes an obvious problem. Manual brushing will have to be repeated more often to meet these objectives. *Herbicide use will increase to get adequate control in a cost effective manner. Spot treatments (both manual and herbicide) should be adequate to achieve growth responses while still leaving some vegetation untreated for non timber purposes.*

Brushing is the activity likely to change the most in response to a growth strategy. Depending on the success of site preparation in controlling brush, more than half the sites now harvested could require treatment. *In particular, brushing in drier sites will need to be increased substantially.* Currently, less than 9% (likely only 4%) of sites are brushed to ensure survival on richer, moister sites. A more challenging growth objective will

require more treatment. In addition, herbicide treatments may need to be increased so that vegetation control is more effective than in current manual treatments.

5.3 Set Administrative Requirements to Match the Growth Strategy

In order to be accepted as a legitimate part of the TSA analysis in the future, any changes in greenup delay need to be demonstrated as genuine current practice to the Chief Forester. The focus must change from survival to growth. The only way to accomplish this task is to change the administrative requirements for future silviculture prescriptions, particularly free growing standards.

Free growing standards are directly related to greenup height. Clearly, the earlier free growing is reached, the earlier greenup will be achieved. Because free growing is a legal obligation, performance is already being monitored. It is not necessary to have a separate system to validate actions on the ground. In addition, free growing is results oriented. It is not necessary to require an ultimately unenforceable set of silviculture activities; it is up to the individual licensee to reach free growing standards in the time frame agreed.

New Enhanced Silviculture Standards for Free Growing

In TSAs where greenup delay limits wood supply, initial growth is a silvicultural priority. In order to meet this challenge, a set of Enhanced Silviculture Standards for Free Growing need to be developed. In particular, the minimum height requirements may need to be increased and the maximum free growing delay decreased in order to reduce greenup delay..

A committee charged by the Regional Manager to develop these standards should be struck. In order to improve acceptance by Districts and Licensees, it is recommended that membership consist of:

- Regional Silviculture representative
- Two District representatives, East and West Kootenays
- Industry representation (maximum of 2)

Application of Enhanced Silviculture Standards

Enhanced Standards may not be required on all stands or TSAs. Plans need to be developed by TSA, designating TSAs or planning units within TSAs for application of these standards. This process will ensure that the extra cost of meeting these standards will be concentrated in areas where it is most needed.

5.4 *Future work*

A number of projects can be carried out in the future to capitalize on the work in this study:

- Analyze actual greenup delay again for all future TSRs. As the data changes over time, greenup delay will have to be reanalyzed to ensure that the values used in TSRs is accurate. It also provides an opportunity to evaluate the long term performance of Districts and Licensees.

- Analyze the costs and benefits of enhanced silviculture to reduce greenup delay. Economic analysis will provide a way of comparing this strategy with other mitigation strategies.

- Maintain and increase PROBE installations to monitor the treatment effects of vegetation control treatments on an operational basis. These local data will be useful in projecting greenup delays in the future.

- Maintain and increase the RPA program to validate the actual growth of plantations. In particular, the range of species and sites need to be expanded. This data will be useful in projecting future greenup delays.

- Investigate, in conjunction with the Ministry of Environment, whether greenup heights can be reduced in some TSAs to 2 m from the current default of 3 m.

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Table 1: Greenup ages and regeneration delays for the Base Case

1 - F,L,Py,(Pw)-g	20	4.94	9.88	14.82	12.15	17.09	15.12	20.06	20.74	25.68	32.7	37.64
2 - F,L,Py,(Pw)-m	17	6.82	10.94	17.76	13.59	20.41	17.15	23.97	23.94	30.76	38.79	45.61
3 - F,L,Py,(Pw)-p(l)	12	6.97	13.83	20.8	17.7	24.67	22.97	29.94	33.36	40.33	58.13	65.1
4 - H,C-all	18	4.53	11.8	16.33	14.22	18.75	17.36	21.89	23.5	28.03	37.23	41.76
5 - S,B-g,m	17	4.85	13.13	17.98	17.09	21.94	21.49	26.34	28.82	33.67	42.83	47.68
6 - S,B-p	10	6.8	19.51	26.31	26.41	33.21	34.1	40.9	46.98	53.78	71.84	78.64
7 - Pl,(Pa)-g,m	18	5.52	9.23	14.75	11.76	17.28	14.91	20.43	20.71	26.23	33.49	39.01
8 - Pl,(Pa)-p,(l)	11	6.73	11.81	18.54	16.53	23.26	22.51	29.24	33.9	40.63	61.44	68.17
9 - Deciduous	20	5.5	0	5.5	0	5.5	0	5.5	0	5.5	0	5.5

Table 2 Greenup ages and regeneration delays for Current Practice

Analysis Unit	Site Index (50 yrs)	Regen Delay-Current Practice	Age at Avg. Ht. 1.3 m (yrs)	Total Age To 1.3 m (yrs)	Age at Avg. Ht. 2 m (yrs)	Total Age To 2 m (yrs)	Age at Avg. Ht. 3 m (yrs)	Total Age To 3 m (yrs)	Age at Avg. Ht. 5 m (yrs)	Total Age To 5 m (yrs)	Age at Avg. Ht. 9 m (yrs)	Total Age To 9 m (yrs)
1 - F,L,Py,(Pw)-g	20	2.13	5.91	8.04	8.44	10.57	11.67	13.8	17.29	19.42	29.25	31.38
2 - F,L,Py,(Pw)-m	17	3.44	5.91	9.35	8.44	11.88	11.67	15.11	18.46	21.9	33.31	36.75
3 - F,L,Py,(Pw)-p(l)	12	4.08	5.91	9.99	8.44	12.52	11.67	15.75	22.06	26.14	46.83	50.91
4 - H,C-all	18	2.52	4.8	7.32	7.81	10.33	12.65	15.17	18.79	21.31	32.52	35.04
5 - S,B-g,m	17	2.61	8.05	10.66	11.72	14.33	16.5	19.11	23.83	26.44	37.84	40.45
6 - S,B-p	10	2.93	8.58	11.51	15.06	17.99	25.88	28.81	38.76	41.69	63.62	66.55
7 - Pl,(Pa)-g,m	18	2.67	5.44	8.11	8.18	10.85	12	14.67	17.8	20.47	30.58	33.25
8 - Pl,(Pa)-p,(l)	11	3.26	6.57	9.83	9.27	12.53	12.23	15.49	23.62	26.88	51.16	54.42

Table 3 Estimated improvement in height growth due to Enhanced Silviculture Practice

Species	Estimated Improvement (%)	Treatment	Source
Fd	12.8	Mixed Hardwood-Shrub/ ICH, IDF/ Fd/ Cut-stump glyphosate (3 replications)	Simard, 1996
Fd	36.2	Oregon Shrub/forb control	Petersen and Newton, 1985
Fd	39.2	Blackwater Ridge Site Prep in ICH (Mech)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Fd	61.1	Murphy Cr. Site Prep in ICH (Burning)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Fd	139.9	Begbie Cr. Site Prep in ICH (Mech)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Lw	64.8	Murphy Cr. Site Prep in ICH (Burning)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Pl	34.8	SX86405N, grass control	Unpublished report, Nelson Forest Region
Pl	42.6	Blackwater Ridge Site Prep in ICH (Mech)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Pw	69.1	Murphy Cr. Site Prep in ICH (Burning)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Se	36.4	Mounding for Artificial Regeneration of Spruce, Site 2	Hawkins et al, 1995
Se	36.4	EP 1179 Bush River Brushing Trials	Clement and Keeping, 1996
Se	45.9	Cr. Site Prep in ICH (Mech)	Thompson, C.F. Ep1001.02, Unpublished data on file at Nelson Forest Region
Se	50.4	Mounding for Artificial Regeneration of Spruce, Site 1	Hawkins et al, 1995

Table 4: Currently available and future potential genetic gain for height growth to 3 m by species (adapted from Yanchuk 1996)

Species	Future Potential Genetic Gain (%)
Fd	16.0
Se	14.0
Lw	12.0
Pl	14.0

Table 5: Greenup delays for Enhanced Silviculture Practice

Analysis Unit	Site Index	Regen Delay- Current Practice	Total Silv Hl Gain	Total Age To 1.3 m (yrs)	Total Age To 2 m (yrs)	Total Age To 3 m (yrs)	Total Age To 5 m (yrs)	Total Age To 9 m (yrs)
1 - F,L,Py,(Pw)-g	20	2.13	45.8%	6.19	7.93	10.15	14.01	22.22
2 - F,L,Py,(Pw)-m	17	3.44	45.8%	7.50	9.24	11.46	16.12	26.32
3 - F,L,Py,(Pw)-p(l)	12	4.08	45.8%	8.14	9.88	12.10	19.23	36.24
4 - H,C-all	18	2.52	20.0%	6.52	9.03	13.06	18.18	29.62
5 - S,B-g,m	17	2.61	24.2%	9.09	12.04	15.89	21.79	33.07
6 - S,B-p	10	2.93	24.2%	9.84	15.05	23.76	34.13	54.14
7 - Pl,(Pa)-g,m	18	2.67	39.4%	6.75	8.80	11.67	16.01	25.59
8 - Pl,(Pa)-p,(l)	11	3.26	39.4%	8.19	10.21	12.43	20.97	41.61

Table 6: Greenup ages and regeneration delays using RPA Data

Analysis Unit	Site Index	Regen Delay-Current Practice	Age at Avg. Ht. 1.3 m (yrs)	Total Age To 1.3 m (yrs)	Age at Avg. Ht. 2 m (yrs)	Total Age To 2 m (yrs)	Age at Avg. Ht. 3 m (yrs)	Total Age To 3 m (yrs)	Age at Avg. Ht. 5 m (yrs)	Total Age To 5 m (yrs)	Age at Avg. Ht. 9 m (yrs)	Total Age To 9 m (yrs)
5 - S,B-g,m	17	2.61	8.01	10.62	11.07	13.68	13.95	16.56				
6 - S,B-p	10	2.93	11.1	14.03	15.05	17.98	18.77	21.7				
7 - Pl,(Pa)-g,m	18	2.67	4.76	7.43	6.36	9.03	8.39	11.06	12.08	14.75	18.99	21.66
8 - Pl,(Pa)-p,(l)	11	3.26	5.94	9.2	7.97	11.23	10.6	13.86	15.48	18.74		

Table 7: Comparison of greenup ages between base and current practice

Analysis Unit	Site Index	Total Age To 1.3 m Base	Total Age To 1.3 m Current	Total Age To 2 m Base	Total Age To 2 m Current	Total Age To 3 m Base	Total Age To 3 m Current	Total Age To 5 m Base	Total Age To 5 m Current	Total Age To 9 m Base	Total Age To 9 m Current
1 - F,L,Py,(Pw)-g	20	14.82	8.04	17.09	10.57	20.06	13.8	25.68	19.42	37.64	31.38
2 - F,L,Py,(Pw)-m	17	17.76	9.35	20.41	11.88	23.97	15.11	30.76	21.9	45.61	36.75
3 - F,L,Py,(Pw)-p(l)	12	20.8	9.99	24.67	12.52	29.94	15.75	40.33	26.14	65.1	50.91
4 - H,C-all	18	16.33	7.32	18.75	10.33	21.89	15.17	28.03	21.31	41.76	35.04
5 - S,B-g,m	17	17.98	10.66	21.94	14.33	26.34	19.11	33.67	26.44	47.68	40.45
6 - S,B-p	10	26.31	11.51	33.21	17.99	40.9	28.81	53.78	41.69	78.64	66.55
7 - Pl,(Pa)-g,m	18	14.75	8.11	17.28	10.85	20.43	14.67	26.23	20.47	39.01	33.25
8 - Pl,(Pa)-p,(l)	11	18.54	9.83	23.26	12.53	29.24	15.49	40.63	26.88	68.17	54.42

Table 8: Comparison of greenup ages between Current Practice and Enhanced Silviculture Practice

Analysis Unit	Site Index	Total Age To 1.3 m Current	Total Age To 1.3 m Silv Improved	Total Age To 2 m Current	Total Age To 2 m Silv Improved	Total Age To 3 m Current	Total Age To 3 m Silv Improved	Total Age To 5 m Current	Total Age To 5 m Silv Improved	Total Age To 9 m Current	Total Age To 9 m Silv Improved
1 - F,L,Py,(Pw)-g	20	8.04	6.19	10.57	7.93	13.8	10.15	19.42	14.01	31.38	22.22
2 - F,L,Py,(Pw)-m	17	9.35	7.50	11.88	9.24	15.11	11.46	21.9	16.12	36.75	26.32
3 - F,L,Py,(Pw)-p(l)	12	9.99	8.14	12.52	9.88	15.75	12.10	26.14	19.23	50.91	36.24
4 - H,C-all	18	7.32	6.52	10.33	9.03	15.17	13.06	21.31	18.18	35.04	29.62
5 - S,B-g,m	17	10.66	9.09	14.33	12.04	19.11	15.89	26.44	21.79	40.45	33.07
6 - S,B-p	10	11.51	9.84	17.99	15.05	28.81	23.76	41.69	34.13	66.55	54.14
7 - Pl,(Pa)-g,m	18	8.11	6.75	10.85	8.80	14.67	11.67	20.47	16.01	33.25	25.59
8 - Pl,(Pa)-p,(l)	11	9.83	8.19	12.53	10.21	15.49	12.43	26.88	20.97	54.42	41.61

Table 9: Comparison of greenup ages between Enhanced Silviculture Practice and RPA data

Analysis Unit	Site Index	Total Age To 1.3 m RPA	Total Age To 1.3 m Silv Improved	Total Age To 2 m RPA	Total Age To 2 m Silv Improved	Total Age To 3 m RPA	Total Age To 3 m Silv Improved	Total Age To 5 m RPA	Total Age To 5 m Silv Improved	Total Age To 9 m RPA	Total Age To 9 m Silv Improved
5 - S,B-g,m	17	10.62	9.09	13.68	12.04	16.56	15.89				
6 - S,B-p	10	14.03	9.84	17.98	15.05	21.7	23.76				
7 - Pl,(Pa)-g,m	18	7.43	6.57	9.03	8.54	11.06	11.28	14.75	15.44	21.66	24.61
8 - Pl,(Pa)-p,(l)	11	9.2	7.97	11.23	9.91	13.86	12.03	18.74	20.20		

Table 10: Annual wood supply gains from varying greenup delay scenarios

District	Scenario		Short Term (3 decades)			Long Term (> 10 decades)		
			Average Annual Harvest (m^3/yr)	Absolute Volume Gain (m^3/yr)	Percentage Volume Gain (%)	Average Annual Harvest (m^3/yr)	Absolute Volume Gain (m^3/yr)	Percentage Volume Gain (%)
Revelstoke	Base		157,180	N/A	N/A	120,000	N/A	N/A
	Current		159,980	2,800	1.78	120,000	0	0.0
	Enhanced	*Genetics*		1,704	1.08		820	0.68
		Silviculture Practices		2,452	1.56		1,180	0.98
		Total	164,136	6,956	4.43	122,000	2,000	1.67
Cranbrook	Base		736,000	N/A	N/A	820,000	N/A	N/A
	Current		765,548	29,548	4.01	825,000	5,000	0.61
	Enhanced	*Genetics*		23,009	3.13		2,050	0.25
		Silviculture Practices		33,110	4.5		2,950	0.36
		Total	821,667	85,667	11.64	830,000	10,000	1.22

Table 11: Summary of site preparation methods on stocked openings only

Site Preparation Technique	Total Opening Area (ha)
Burning	18841.1 30.53%
Mechanical	17615 28.54%
Other	1305 2.11%
Unprepared	23954.4 38.81%
Grand Total:	**61715.5**

Table 12: Site preparation and brushing by year

Year Logged	Area Logged (Ha)	Area Site Prepared within Area Logged (Ha)	Area Site Prepared (%)	Area Logged (Ha)	Area Brushed within Area Logged (Ha)	Area Brushed (%)
1990	19167.2	11341.9	59.2%	19167.2	2384	12.4%
1991	20226.1	10731.7	53.1%	20226.1	1317.1	6.5%
1992	20424.3	8626.4	42.2%	20424.3	1559.5	7.6%
1993	19367.5	6488.1	33.5%			
1994	15789.4	3063.7	19.4%			
TOTAL/ AVERAGE	**94974.5**	**40251.8**	**42.4%**	**59817.6**	**5260.6**	**8.8%**

Table 13: Summary of brushing on stocked openings only

Treatment	Total Opening Area
Brushed	7412.7 12.01%
Not Brushed	54302.8 87.99%
Grand Total:	61715.5

Table 14: Summary of site preparation by district and year

District	Yr Logged	Area Logged (Ha)	Area Site Prepared within Area Logged (Ha)	Area Site Prepared Annually (%)
Arrow	1990	2851.7	1213.3	42.5%
	1991	2612.9	734	28.1%
	1992	3809.3	1033	27.1%
	1993	3693.5	720.2	19.5%
	1994	3597.3	604	16.8%
Boundary	1990	5769.7	4801	83.2%
	1991	4874.6	5568.5	114.2%
	1992	3948	2409.8	61.0%
	1993	4450.5	1665	37.4%
	1994	2612.8	430.7	16.5%
Cranbrook	1990	3522.6	1071.9	30.4%
	1991	5203.8	1116.5	21.5%
	1992	4076.6	1166.7	28.6%
	1993	3480.2	1096.8	31.5%
	1994	3504.3	479.5	13.7%
Golden	1990	1270.8	756	59.5%
	1991	1843.4	956.6	51.9%
	1992	1620.2	916.3	56.6%
	1993	1428.2	464.8	32.5%
	1994	720.3	156	21.7%
Invermere	1990	2769	1289.5	46.6%
	1991	3333.3	894.1	26.8%
	1992	3553.7	1148.5	32.3%
	1993	3340.5	964.5	28.9%
	1994	2610	309.3	11.9%
Kootenay Lake	1990	1235.8	874.2	70.7%
	1991	1299.4	949.5	73.1%
	1992	1995.7	1178	59.0%
	1993	1888.3	1110.1	58.8%
	1994	1764.8	711.8	40.3%
Revelstoke	1990	1747.6	1336	76.4%
	1991	1058.7	512.5	48.4%
	1992	1420.8	774.1	54.5%
	1993	1086.3	466.7	43.0%
	1994	979.9	372.4	38.0%
TOTAL/ AVERAGE		**94974.5**	**40251.8**	**42.4%**

Table 15: Summary of brushing by district and year

District	Yr Logged	Area Logged (Ha)	Area Brushed within Area Logged (Ha)	Area Brushed Annually (%)
Arrow	1990	2851.7	566.6	19.9%
	1991	2612.9	372.2	14.2%
	1992	3809.3	333.3	8.7%
Boundary	1990	5769.7	175.2	3.0%
	1991	4874.6	23.8	0.5%
	1992	3948	0	0.0%
Cranbrook	1990	3522.6	6.2	0.2%
	1991	5203.8	3.5	0.1%
	1992	4076.6	6.5	0.2%
Golden	1990	1270.8	32.2	2.5%
	1991	1843.4	89.1	4.8%
	1992	1620.2	171.4	10.6%
Invermere	1990	2769	0	0.0%
	1991	3333.3	0	0.0%
	1992	3553.7	17.6	0.5%
Kootenay Lake	1990	1235.8	135.1	10.9%
	1991	1299.4	94.3	7.3%
	1992	1995.7	152	7.6%
Revelstoke	1990	1747.6	1468.7	84.0%
	1991	1058.7	734.2	69.3%
	1992	1420.8	878.7	61.8%
TOTAL/ AVERAGE		**59817.6**	**5260.6**	**8.8%**

Table 16: Site preparation and brushing by district

District	Total Area Logged 1990-94 (Ha)	Area Site Prepared 1990-94 (Ha)	Area Site Prepared 1990-94 (%)	Area Logged 1990-92 (Ha)	Area Brushed 1990-92 (Ha)	Area Brushed 1990-92 (%)
Arrow	16564.7	4304.5	26.0%	9273.9	1272.1	13.7%
Boundary	21655.6	14875	68.7%	14592.3	199	1.4%
Cranbrook	19787.5	4931.4	24.9%	12803	16.2	0.1%
Golden	6882.9	3249.7	47.2%	4734.4	292.7	6.2%
Invermere	15606.5	4605.9	29.5%	9656	17.6	0.2%
Kootenay Lake	8184	4823.6	58.9%	4530.9	381.4	8.4%
Revelstoke	6293.3	3461.7	55.0%	4227.1	3081.6	72.9%
TOTAL/ AVERAGE	**94974.5**	**40251.8**	**42.4%**	**59817.6**	**5260.6**	**8.8%**

Table 17: Summary of planting on stocked openings only

Stand Origin	Total Opening Area (ha)
Natural	14289.5 23.15%
Planted	47426 76.85%
Grand Total:	**61715.5**

Figure 1: Timber Supply Alternatives, Revelstoke TSA

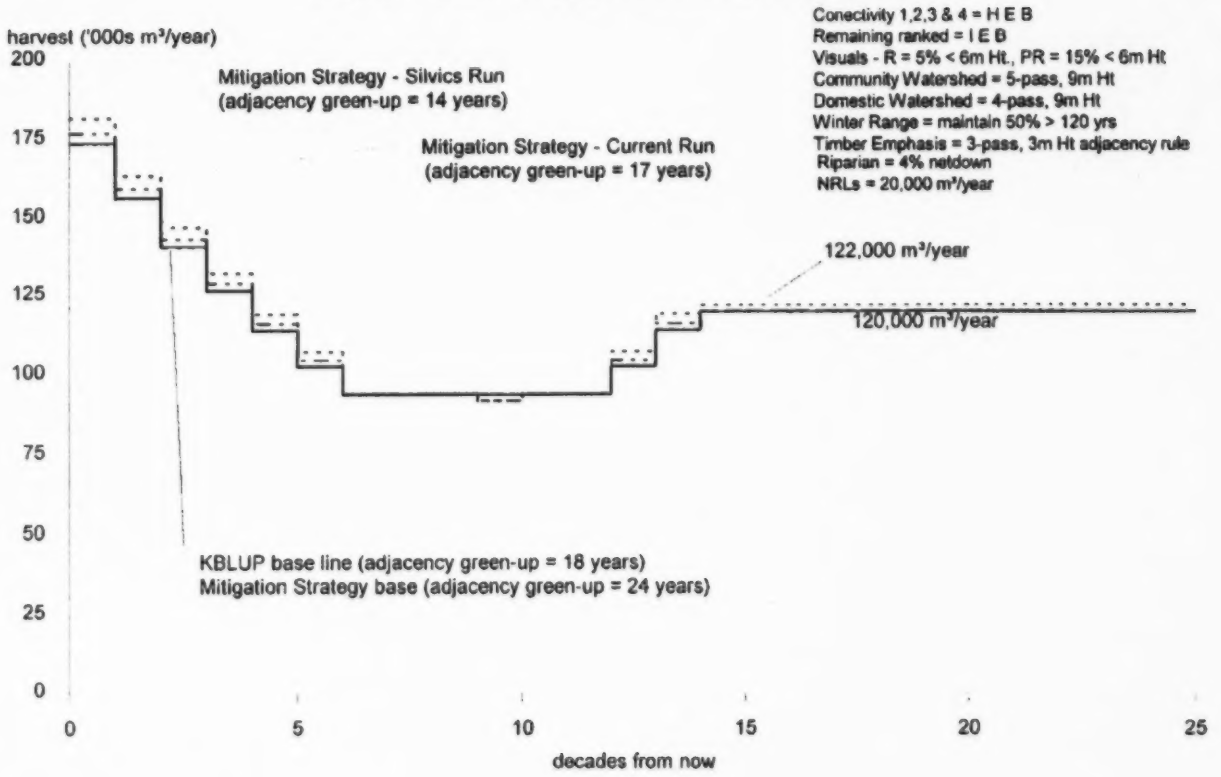
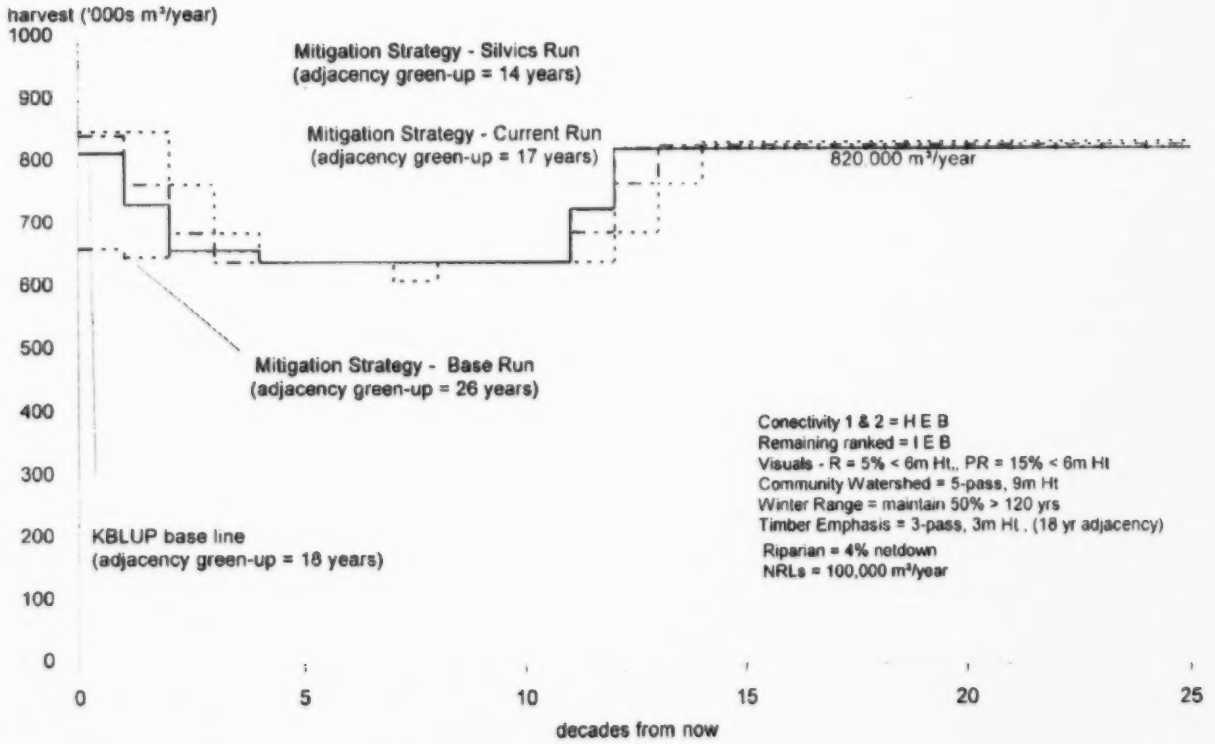


Figure 2: Timber Supply Alternatives, Cranbrook TSA



List of Appendices

Appendix 1 Height-Age Curves and Equations: Douglas-fir (all sites), Western redcedar (all sites), Spruce (good and medium sites), Spruce (poor sites), Lodgepole pine (good and medium sites), Lodgepole pine (poor sites).

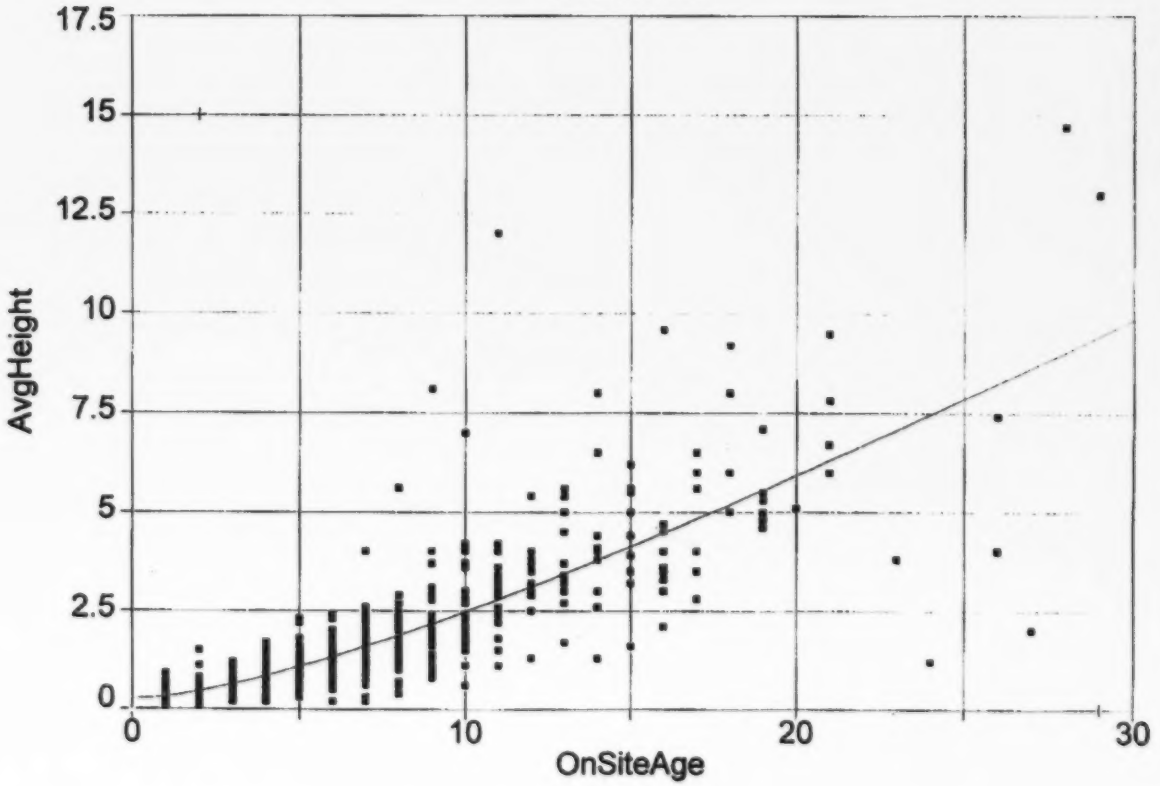
A:\FAALLTRT.XLS

Rank 1 Eqn 2 y=a+bxlnx

r^2=0.72313849 DF Adj r^2=0.72263049 FitStdErr=0.77261835 Fstat=2849.5983

a=0.31650681

b=0.093531358



Rank 1 Eqn 2 y=a+bxlnx

r^2 Coef Det	DF Adj r^2	Fit Std Err	F-value
0.7231384908	0.722630488	0.7726183524	2849.5983273

Parm	Value	Std Error	t-value	95% Confidence Limits		P>|t|
a	0.316506806	0.028393272	11.1472467	0.26087116	0.372142452	0.00000
b	0.093531358	0.001752126	53.38162912	0.090098126	0.096964589	0.00000

Area Xmin-Xmax	Area Precision		
121.94925855	8.767668e-09		
Function min	X-Value	Function max	X-Value
0.282098542	0.36787944	9.4499915798	29
1st Deriv min	X-Value	1st Deriv max	X-Value
-0.912404223	2.900002e-05	0.4084791086	29
2nd Deriv min	X-Value	2nd Deriv max	X-Value
0.0032252196	29	2235.538683	5.800003e-05

Soln Vector
Direct
Covar Matrix
LUDecomp

r^2 Coef Det	DF Adj r^2	Fit Std Err	r^2 Attainable
0.7231384908	0.722630488	0.7726183524	0.4578731875

Source	Sum of Squares	DF	Mean Square	F Statistic	P>F
Regr	1701.0367	1	1701.0367	2849.6	0.00000
Error	651.26058	1091	0.59693912		
Total	2352.2973	1092			
Lack Fit	-623.98285	26	-23.999341	-20.0427	0.00000
Pure Err	1275.2434	1065	1.1974117		

Description: A:\FAALLTRT.XLS

X Variable: OnSiteAge

Xmin:	0	Xmax:	29	Xrange:	29
Xmean:	4.592863678	Xstd:	4.621955917	Xmedian:	3
X@Ymin:	0	X@Ymax:	28	X@Yrange:	28

Y Variable: AvgHeight

Ymin:	0	Ymax:	14.7	Yrange:	14.7
Ymean:	1.1773101555	Ystd:	1.4676915204	Ymedian:	0.6
Y@Xmin:	0.3	Y@Xmax:	13	Y@Xrange:	12.7

Date	Time	File Source
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5.	4	0.835154780765	Y=F(X)
6.	5	1.069171371172	Y=F(X)
7.	6	1.322020980788	Y=F(X)
8.	7	1.590532133306	Y=F(X)
9.	8	1.872450731161	Y=F(X)
10.	9	2.166091387036	Y=F(X)
11.	10	2.470145905775	Y=F(X)
12.	11	2.783569211538	Y=F(X)
13.	12	3.105507118807	Y=F(X)
14.	13	3.435248352196	Y=F(X)
15.	14	3.772191417641	Y=F(X)
16.	15	4.115820986941	Y=F(X)
17.	16	4.465690607151	Y=F(X)
18.	17	4.821409748979	Y=F(X)
19.	18	5.1826339127	Y=F(X)
20.	19	5.549056939201	Y=F(X)
21.	20	5.920404943979	Y=F(X)
22.	21	6.296431467164	Y=F(X)
23.	22	6.676913549303	Y=F(X)
24.	23	7.061648521994	Y=F(X)
25.	24	7.450451357641	Y=F(X)
26.	25	7.843152461622	Y=F(X)
27.	26	8.239595818219	Y=F(X)
28.	27	8.639637422176	Y=F(X)
29.	28	9.043143942909	Y=F(X)
30.	29	9.449991579759	Y=F(X)
31.	30	9.860065075307	Y=F(X)

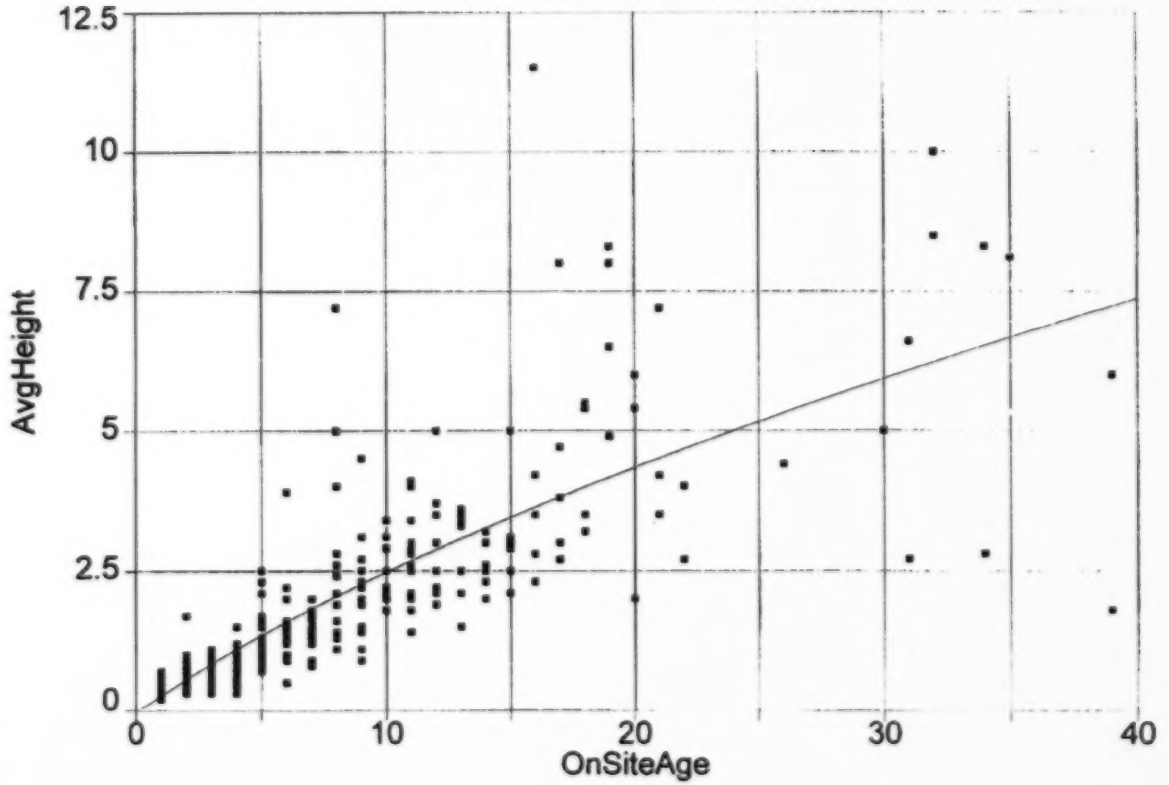
C:\BIODIVER\GERRY\CHAALLTR.XLS

Rank 1 Eqn 9 $y=a+bx^{0.5}\ln x$

r^2=0.64940789 DF Adj r^2=0.64717482 FitStdErr=1.0613442 Fstat=583.48

a=0.25122421

b=0.30456454



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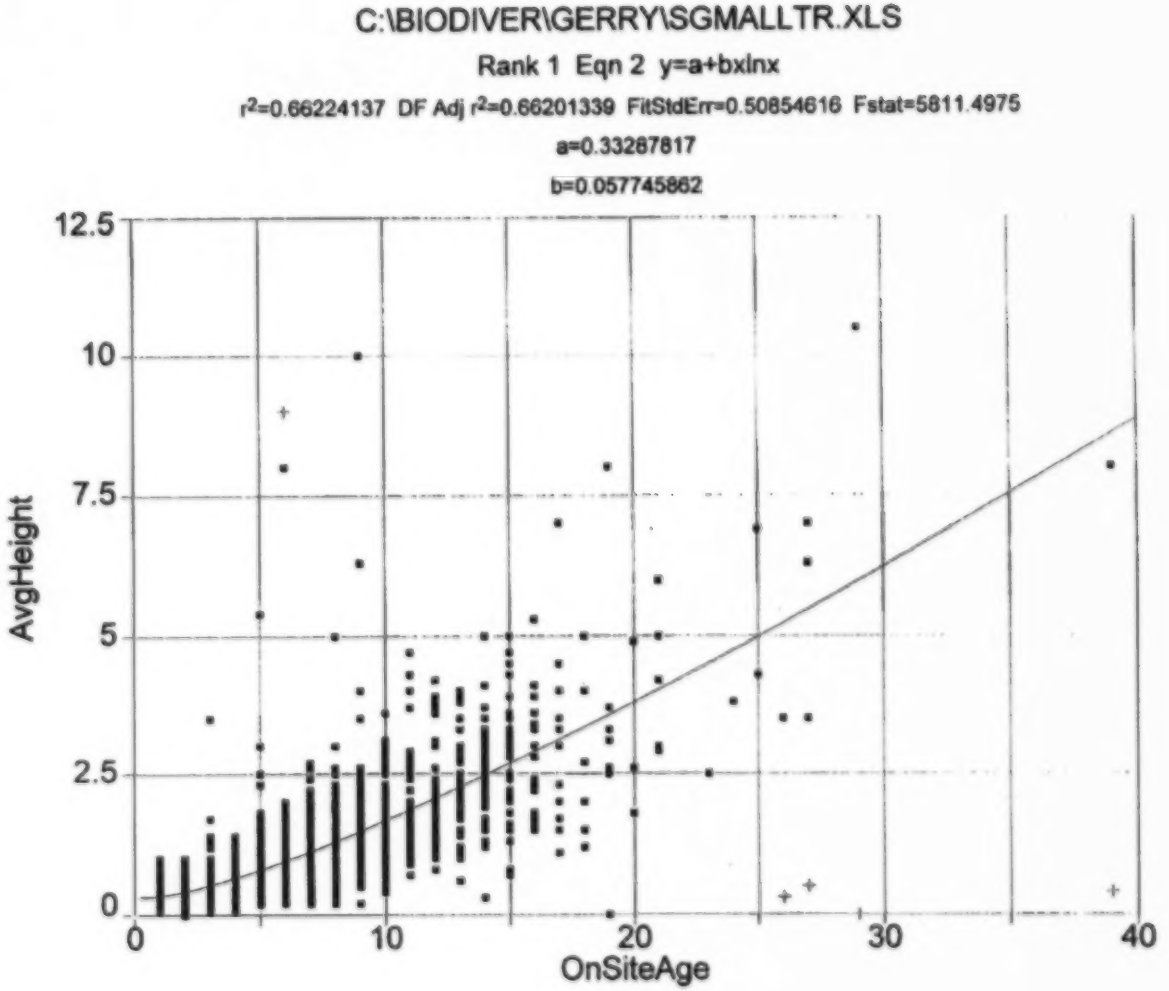
9.	8	2.042535450197	Y=F(X)
10.	9	2.258814307061	Y=F(X)
11.	10	2.468884553892	Y=F(X)
12.	11	2.673401321513	Y=F(X)
13.	12	2.87290639623	Y=F(X)
14.	13	3.067854288666	Y=F(X)
15.	14	3.258631058788	Y=F(X)
16.	15	3.445568200136	Y=F(X)
17.	16	3.6289530777	Y=F(X)
18.	17	3.80903691087	Y=F(X)
19.	18	3.986040973677	Y=F(X)
20.	19	4.160161477612	Y=F(X)
21.	20	4.331573465264	Y=F(X)
22.	21	4.500433950433	Y=F(X)
23.	22	4.66688447665	Y=F(X)
24.	23	4.831053221376	Y=F(X)
25.	24	4.993056741411	Y=F(X)
26.	25	5.153001432076	Y=F(X)
27.	26	5.310984755944	Y=F(X)
28.	27	5.467096284423	Y=F(X)
29.	28	5.62141858616	Y=F(X)
30.	29	5.774027989151	Y=F(X)
31.	30	5.924995237991	Y=F(X)
32.	31	6.074386063535	Y=F(X)
33.	32	6.222261678929	Y=F(X)
34.	33	6.368679213424	Y=F(X)
35.	34	6.513692093327	Y=F(X)
36.	35	6.657350377825	Y=F(X)
37.	36	6.799701056102	Y=F(X)
38.	37	6.940788311113	Y=F(X)
39.	38	7.080653754516	Y=F(X)
40.	39	7.219336636556	Y=F(X)
41.	40	7.356874034124	Y=F(X)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Rank 1 Eqn 2 y=a+bxlnx
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a=0.33287817
b=0.057745862
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10
7.5
5
2.5
0
AvgHeight
0
10
20
30
40
OnSiteAge

1.	0	Error	Y=F(X)
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3.	2	0.412930928357	Y=F(X)
4.	3	0.523199106604	Y=F(X)
5.	4	0.653089217567	Y=F(X)
6.	5	0.7975700644	Y=F(X)
7.	6	0.953678337131	Y=F(X)
8.	7	1.119455979787	Y=F(X)
9.	8	1.293511322126	Y=F(X)
10.	9	1.474803813191	Y=F(X)
11.	10	1.662525778863	Y=F(X)
12.	11	1.856031993765	Y=F(X)
13.	12	2.054795087395	Y=F(X)
14.	13	2.258375921357	Y=F(X)
15.	14	2.466403135776	Y=F(X)
16.	15	2.678558569213	Y=F(X)
17.	16	2.894566583523	Y=F(X)
18.	17	3.114186067581	Y=F(X)
19.	18	3.337204328724	Y=F(X)
20.	19	3.563432345618	Y=F(X)
21.	20	3.792701023138	Y=F(X)
22.	21	4.024858198008	Y=F(X)
23.	22	4.259766216011	Y=F(X)
24.	23	4.497299950539	Y=F(X)
25.	24	4.737345166341	Y=F(X)
26.	25	4.97979715642	Y=F(X)
27.	26	5.224559597335	Y=F(X)
28.	27	5.471543580854	Y=F(X)
29.	28	5.720666789243	Y=F(X)
30.	29	5.9718527885	Y=F(X)
31.	30	6.225030419188	Y=F(X)
32.	31	6.480133268561	Y=F(X)
33.	32	6.737099210877	Y=F(X)
34.	33	6.99587000521	Y=F(X)
35.	34	7.256390942063	Y=F(X)
36.	35	7.518610531579	Y=F(X)
37.	36	7.782480227418	Y=F(X)
38.	37	8.047954181329	Y=F(X)
39.	38	8.314989024277	Y=F(X)
40.	39	8.583543670621	Y=F(X)
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A:\SPALLTRT.XLS

Rank 1 Eqn 9 $y=a+bx^{0.5}\ln x$

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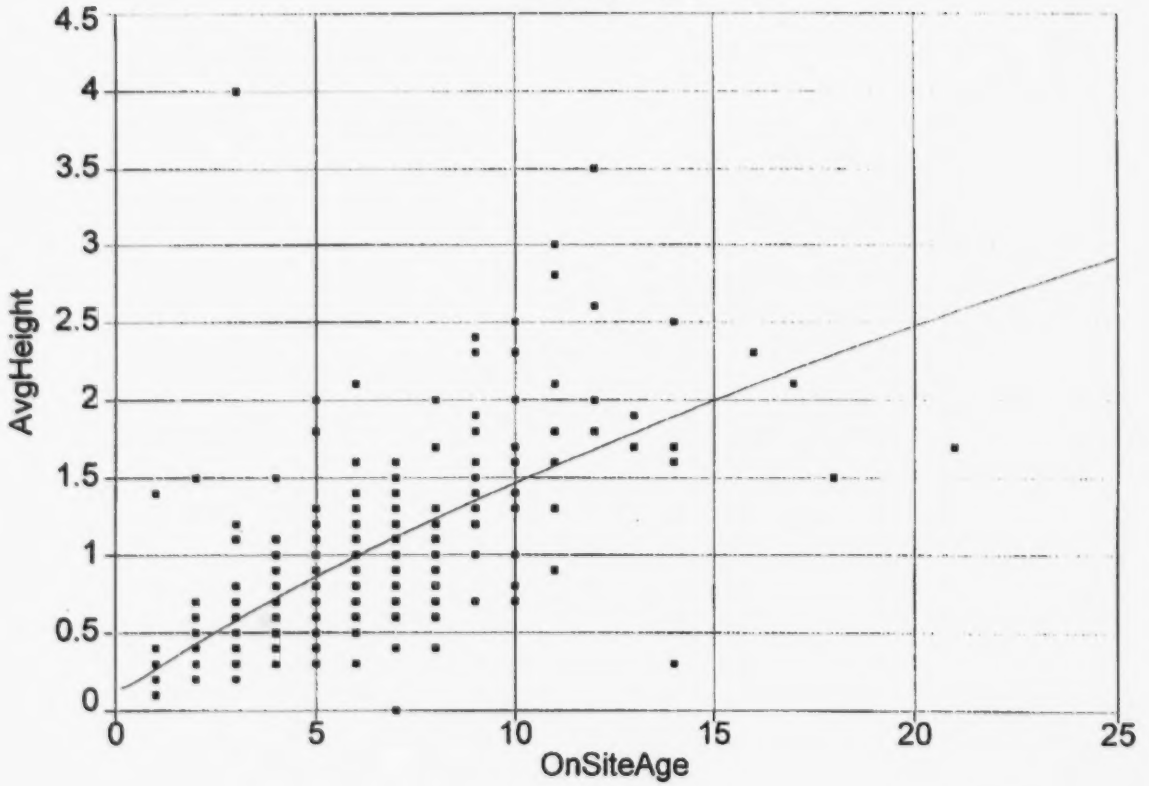
a=0.26555304

b=0.16477735



Rank 1 Eqn 9 $y=a+bx^{0.5}\ln x$

r^2 Coef Det	DF Adj r^2	Fit Std Err	F-value
0.5484246881	0.5456795495	0.4264120015	400.77511398

Parm	Value	Std Error	t-value	95% Confidence Limits		P>|t|
a	0.265553043	0.034395694	7.72053164	0.197893376	0.33321271	0.00000
b	0.164777347	0.008230896	20.01936847	0.148586376	0.180968319	0.00000

Area Xmin-Xmax	Area Precision		
30.714027991	1.029266e-06		
Function min	X-Value	Function max	X-Value
0.1443166462	0.1353353283	2.5644861458	21
1st Deriv min	X-Value	1st Deriv max	X-Value
0.0906938676	21	0.1647773474	0.9999999576
2nd Deriv min	X-Value	2nd Deriv max	X-Value
-0.010043283	2.1000026813	-0.00130325	21

Soln Vector
Direct
Covar Matrix
LUDecomp

r^2 Coef Det	DF Adj r^2	Fit Std Err	r^2 Attainable
0.5484246881	0.5456795495	0.4264120015	0.6115770732

Source	Sum of Squares	DF	Mean Square	F Statistic	P>F
Regr	72.871815	1	72.871815	400.775	0.00000
Error	60.002974	330	0.1818272		
Total	132.87479	331			
Lack Fit	8.3913598	17	0.4936094	2.99351	0.00008
Pure Err	51.611615	313	0.16489334		

Description: A:\SPALLTRT.XLS

X Variable: OnSiteAge

Xmin:	0	Xmax:	21	Xrange:	21
Xmean:	4.4337349398	Xstd:	3.8316310209	Xmedian:	4
X@Ymin:	7	X@Ymax:	3	X@Yrange:	4

Y Variable: AvgHeight

Ymin:	0	Ymax:	4	Yrange:	4
Ymean:	0.7701807229	Ystd:	0.6335885166	Ymedian:	0.5
Y@Xmin:	0.5	Y@Xmax:	1.7	Y@Xrange:	1.2

Date	Time	File Source
Sep 20, 1996	3:44:39 PM	a:\spalltrt.xls

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3.	2	0.427077379824	Y=F(X)
4.	3	0.57909999798	Y=F(X)
5.	4	0.722412858299	Y=F(X)
6.	5	0.85855583359	Y=F(X)
7.	6	0.988743756882	Y=F(X)
8.	7	1.11389180402	Y=F(X)
9.	8	1.234699063175	Y=F(X)
10.	9	1.351711555789	Y=F(X)
11.	10	1.465365028728	Y=F(X)
12.	11	1.576013924824	Y=F(X)
13.	12	1.683951364573	Y=F(X)
14.	13	1.789423250058	Y=F(X)
15.	14	1.892638449771	Y=F(X)
16.	15	1.993776310348	Y=F(X)
17.	16	2.092992303731	Y=F(X)
18.	17	2.190422346151	Y=F(X)
19.	18	2.28618615262	Y=F(X)
20.	19	2.380389878662	Y=F(X)
21.	20	2.473128226876	Y=F(X)
22.	21	2.564486145815	Y=F(X)
23.	22	2.654540214216	Y=F(X)
24.	23	2.743359779422	Y=F(X)
25.	24	2.831007901695	Y=F(X)
26.	25	2.917542143676	Y=F(X)
	26	> 3u	

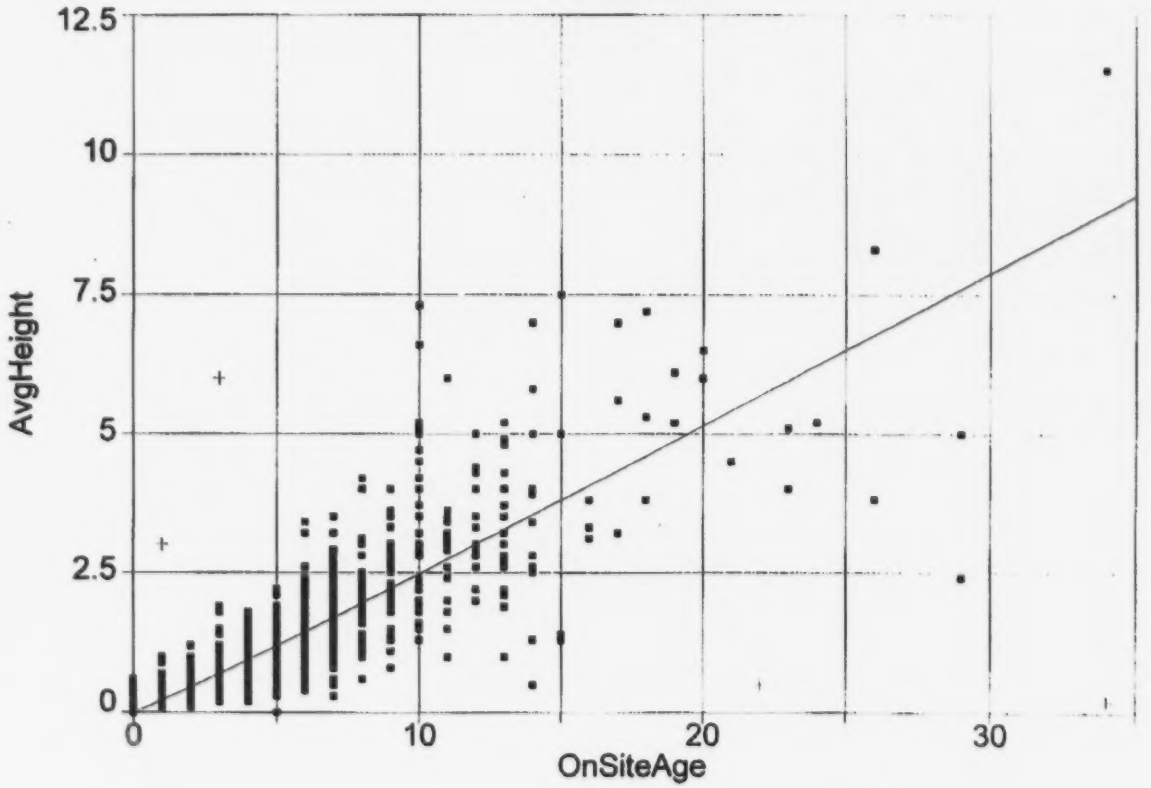
C:\BIODIVER\GERRY\PGMALLTR.XLS

Rank 1 Eqn 8156 [Power_] $y=ax^b$

r^2=0.74867905 DF Adj r^2=0.74841519 FitStdErr=0.51093845 Fstat=5677.9279

a=0.2175858

b=1.0553356



1.	0	0	Y=F(X)
2.	1	0.21758579843	Y=F(X)
3.	2	0.452187141446	Y=F(X)
4.	3	0.693671062842	Y=F(X)
5.	4	0.939736013862	Y=F(X)
6.	5	1.189264498642	Y=F(X)
7.	6	1.441588271266	Y=F(X)
8.	7	1.696260576965	Y=F(X)
9.	8	1.952960831491	Y=F(X)
10.	9	2.211447377984	Y=F(X)
11.	10	2.471531312913	Y=F(X)
12.	11	2.733060780866	Y=F(X)
13.	12	2.995910965836	Y=F(X)
14.	13	3.259977404258	Y=F(X)
15.	14	3.525171343813	Y=F(X)
16.	15	3.7914164193	Y=F(X)
17.	16	4.058646208168	Y=F(X)
18.	17	4.326802392088	Y=F(X)
19.	18	4.595833347239	Y=F(X)
20.	19	4.865693044932	Y=F(X)
21.	20	5.136340181418	Y=F(X)
22.	21	5.407737479978	Y=F(X)
23.	22	5.679851124554	Y=F(X)
24.	23	5.952650295268	Y=F(X)
25.	24	6.22610678383	Y=F(X)
26.	25	6.500194672341	Y=F(X)
27.	26	6.774890062902	Y=F(X)
28.	27	7.050170848351	Y=F(X)
29.	28	7.326016516566	Y=F(X)
30.	29	7.602407982404	Y=F(X)
31.	30	7.879327442541	Y=F(X)
32.	31	8.15675824944	Y=F(X)
33.	32	8.434684801384	Y=F(X)
34.	33	8.713092446087	Y=F(X)
35.	34	8.99196739585	Y=F(X)
36.	35	9.271296652574	Y=F(X)

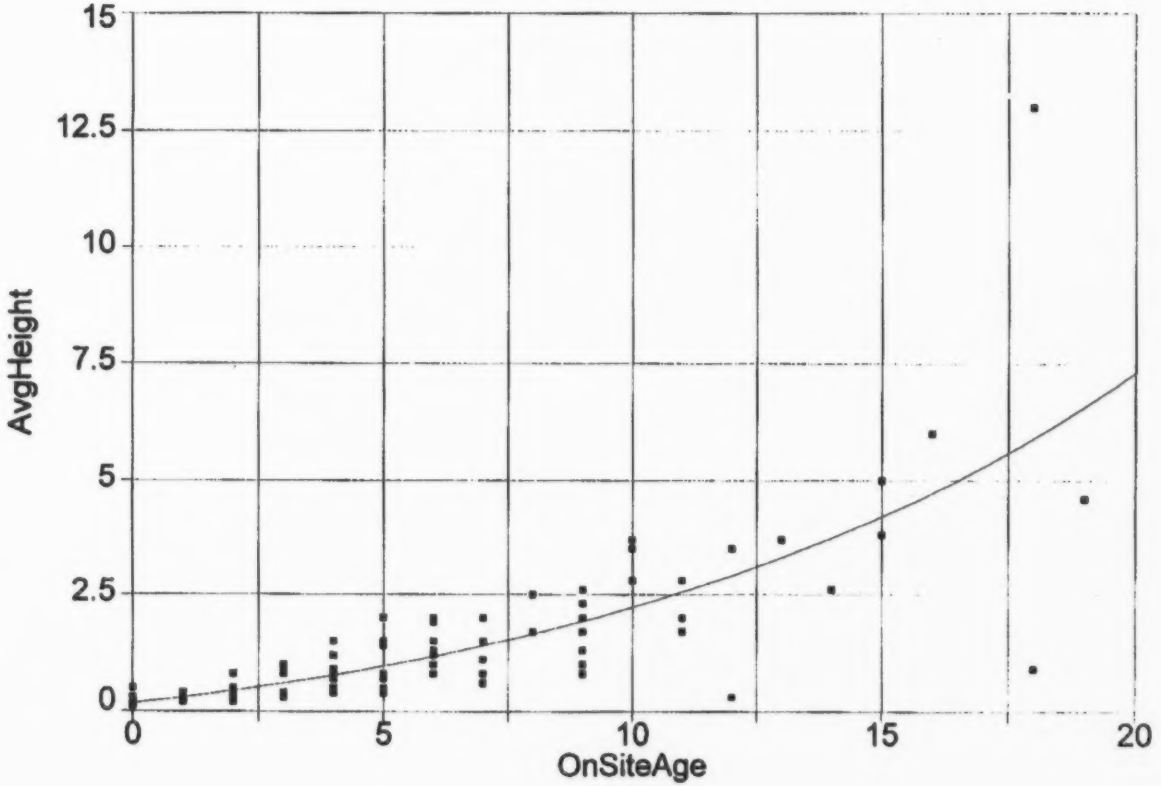
A:\PPALLTRT.XLS

Rank 1 Eqn 8002 [Exponential] y=a+bexp(-x/c)

r^2=0.63231283 DF Adj r^2=0.62389251 FitStdErr=0.91540059 Fstat=113.50042

a=-1.2445896 b=1.4030409

c=-11.063685



Rank 1 Eqn 8002 [Exponential] y=a+bexp(-x/c)

r^2 Coef Det	DF Adj r^2	Fit Std Err	F-value
0.6323128283	0.6238925114	0.9154005894	113.50041523

Parm	Value	Std Error	t-value	95% Confidence Limits		P>|t|
a	-1.24458965	0.735689218	-1.69173289	-2.69993046	0.210751162	0.09306
b	1.403040891	0.64595534	2.172040083	0.125211686	2.680870097	0.03164
c	-11.0636852	2.670844939	-4.14239145	-16.3471522	-5.78021834	0.00006

Area Xmin-Xmax	Area Precision		
47.286392051	0		
Function min	X-Value	Function max	X-Value
0.1584512424	1.76745e-10	6.5698407381	19
1st Deriv min	X-Value	1st Deriv max	X-Value
0.1268149681	1.76745e-10	0.7063135124	19
2nd Deriv min	X-Value	2nd Deriv max	X-Value
0.0114622719	1.42748e-07	0.0638407095	19

Procedure	Minimization	Iterations	
LevMarqdt	Least Squares	9	
r^2 Coef Det	DF Adj r^2	Fit Std Err	r^2 Attainable
0.6323128283	0.6238925114	0.9154005894	0.6908412863

Source	Sum of Squares	DF	Mean Square	F Statistic	P>F
Regr	190.21722	2	95.108608	113.5	0.00000
Error	110.61049	132	0.83795824		
Total	300.8277	134			
Lack Fit	17.606982	16	1.1004364	1.37254	0.16752
Pure Err	93.003506	116	0.80175436		

Description: A:\PPALLTRT.XLS

X Variable: OnSiteAge

Xmin:	0	Xmax:	19	Xrange:	19
Xmean:	4.4740740741	Xstd:	4.384214611	Xmedian:	3
X@Ymin:	0	X@Ymax:	18	X@Yrange:	18

Y Variable: AvgHeight

Ymin:	0.1	Ymax:	13	Yrange:	12.9
Ymean:	1.0585185185	Ystd:	1.4983266878	Ymedian:	0.5
Y@Xmin:	0.1	Y@Xmax:	4.6	Y@Xrange:	4.5

Date	Time	File Source
Sep 20, 1996	2:50:52 PM	a:\ppalltrt.xls

1.	0	0.158451242354	Y=F(X)
2.	1	0.291173990796	Y=F(X)
3.	2	0.436451845839	Y=F(X)
4.	3	0.595472476541	Y=F(X)
5.	4	0.76953590129	Y=F(X)
6.	5	0.960065115653	Y=F(X)
7.	6	1.168617725591	Y=F(X)
8.	7	1.396898681123	Y=F(X)
9.	8	1.646774214565	Y=F(X)
10.	9	1.920287097263	Y=F(X)
11.	10	2.219673339571	Y=F(X)
12.	11	2.547380470581	Y=F(X)
13.	12	2.906087547056	Y=F(X)
14.	13	3.298727055131	Y=F(X)
15.	14	3.728508883851	Y=F(X)
16.	15	4.198946566506	Y=F(X)
17.	16	4.713886004315	Y=F(X)
18.	17	5.277536907267	Y=F(X)
19.	18	5.894507209155	Y=F(X)
20.	19	6.569840738149	Y=F(X)
21.	20	7.309058450879	Y=F(X)